

# Eco-design practices in Europe fostering automotive vehicles recyclability in Brazil

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**Abstract:** This article aims at presenting how eco-design practices in Europe are promoting the diffusion of vehicles recyclability worldwide. Even developing countries like Brazil are fostering recycling activities through vehicles production and consumption encompassing ELV Directive 2000/53/EC. In this sense, we stated and demonstrated that the environmentally conscious designing practices of the European automotive sector are bringing good results to the Brazilian manufacturing and recycling materials sectors. Besides, since the early nineties, after Rio-92 World Summit on Environment, issues such as pollution prevention, waste minimization, materials recovery and end-of-life components, and products recycling have become a subject of great interest for government policies and environmental legislation in Brazil. This paper is based on a one-year research on eco-design and materials recycling conducted in France in 2004/2005 by Heloisa de Medina, and it is also connected to a research program on product development management for recycling (PROCICLE) in Brazil in which both authors have been involved since 2002.

**Keywords:** eco-design, environmental regulation, vehicles recyclability.

## 1. Introduction

Automakers are nowadays redefining their product according to the consumers' expectations reaching to improve the engine performance as well as to rend the new models more comfortable, safer, easier to drive, and environmental friendly. To conceive and produce vehicles with respect both to the consumers and to the environment has been a constantly growing commitment from the nineties. The way automotive companies in Europe are designing their new vehicles is widely changing the way these vehicles are being produced, and should be recycled at the end of their lives worldwide. It is the starting up of a new pattern of global competitiveness that includes from now on the environmental dimension side by side with organisational and technological innovation at the product, the material, and process levels.

In this sense:

However competitiveness is not the only criterion for evaluating and selection of assembly systems. (...) Environmental friendliness has become another important criterion in recent years. Although final assembly is a relatively "clean" process as far as air and water pollution is concerned, it may play a pivotal role with regard to the recycling of motor vehicles. In other words, how to incorporate 'disassemblability' to product designs, as well as how to design disassembly processes themselves

could be a critical issue in the coming decades (SHIMOKAWA; JÜRGENS; FUJIMOTO, 1997 p. 7-8).

Vehicle recyclability is crucial to achieve environmental friendliness saving raw materials and energy, and reducing final disposals as well. ELV recycling systems organization concerns, not only engineers, designers, and automotive companies and theirs suppliers, for technical and industrial aspects, but also governmental agencies and non-governmental organizations, for the political and legal aspects involved.

The automobile companies, for instance, are expected to set up technical and economical solutions for end-of-life vehicles. In short they have to conceive a "disassembly line", back to the auto-parts and materials producers. Automotive designers and engineers have to consider the vehicle life-cycle from the materials selection up to their recovery from ELV passing through vehicle assembly and disassembly techniques as well as auto-parts, components sub-assembled systems production provided by different suppliers. For these purposes long run partnerships were established between carmakers and their suppliers that, from now on, are working in network sharing risks and profits, and also getting more innovative solutions to foster automotive materials recyclability.

Furthermore, interactive practices, multidisciplinary competences and intersectorial public policies are required to optimise the synergy of automotive chain with regard to environmental practices. We are going to show in this article how important is that synergy and how far it can get good results on diffusing best environmental practices. The article is organised as follows: firstly a brief overview of Brazilian automotive sector and of the regulatory framework on ELV in Europe and in Brazil are presented, secondly the eco-design concept and practices are discussed, and finally some open questions and final remarks are pointed out concerning economic and technological aspects of ELV recycling in Brazil and environmental management practices required by recycling activities to become a new and sound industrial activity in great developing countries like Brazil.

### 1.1. Brazilian automotive industry: a brief overview

The Brazilian automotive history started in the 1930's with the first trucks, buses and cars assembled from imported parts, components and engines. After II World War a second wave of industrialization settled the basis of an increasing vertical integration, trade barriers and regulations on import of vehicles and their parts protected the automotive industry in Brazil. It is called the nationalization period. After the middle 1990's the third still ongoing wave came to Brazil, while the automotive industry was passing through a worldwide restructuring process at the production level as well as the industrial organization. This period, which started by the 1970's oil shocks, was strongly increased by the Japanese boom at the 1980's, and arrived at its peak during the Rio 92 World Summit – the second United Nations Conference on Environment and Development realized in Rio de Janeiro, where the sustainable development proposals brought out the basis of the new environmental friendly production paradigm.

The nineties were also a period of radical changes in Brazilian economy in both national and regional levels. An opening up of the economy, including for the automotive sector, in the early 1990's, the reduction of the inflation and a new regional community MERCOSUL free trade agreement with Argentina, Uruguay and Paraguay in the middle 1990's are some main milestones. Resumed the national conditions that transformed Brazil in an attractive market for new automotive investments as follow:

“A number of conditions have favoured the installation and experimentation of new production methods. Incentives at the level of federal government, state government, and municipality government (such as: tax breaks – at state level-, land donations – at municipal level – and BNDES – Brazilian Development Bank – subsidized lines of credit – at federal level-), low labour cost, weak labour unions (except for São Paulo), and a growing market, have driven automotive TNCs to

make Greenfield investment and experiment new modularisation strategies (NAPOLLI, 2002).

Besides, at international level, big car companies were improving their efficiency and competitiveness by means of a flexible manufacturing organization and a global process of technological innovation including environmental innovations to cope with the requirements of the new environmental paradigm. Green vehicles have to be made of green materials at green plants. Industrial Ecology as a new field of knowledge came to help production engineering in this restructuring process.

As a consequence Brazil took advantage of this global restructuring process toward more flexible and greener production organisation. In this context the new entrants car companies and the new plants, made by the companies already present in the country, built up their plants in phase with the state-of-art at organisational and technological innovations and with the best environmental practices as well. Nowadays, in 2006, almost all global vehicles manufactures (car, trucks and buses) have modern and clean plants in Brazil. Moreover Brazilian new plants such as Renault and Volkswagen-Audi in the state of Paraná, PSA - Peugeot-Citroen and Volkswagen Trucks in Rio de Janeiro, and Ford in Bahia are the cleanest industrial facilities of theirs companies in the world.

Brazil features the seventh largest car production, the sixth truck production, and the second bus production – just behind China- with almost 3 million vehicles produced in 2007. We estimate that at around 1 million vehicles are new generation ones. That means they were conceived to be 95% recyclable according to the European Directive on ELV. The Country is also a leadership concerning environmental innovations, since in 2007 and 2008, only a handful of new fuel cell buses were delivered or entered into service. These include the fifth Van Hool bus placed into demonstration in the US, the first outside of California; the first fuel cell bus in Brazil, and two buses with automotive fuel cells being tested by US universities; two additional Hyundai buses in South Korea (JERRAM, 2008).

The Figure 1 shows the existent companies in the early 2000 printed in blue, mainly located in the state of São Paulo (automobile), and Rio Grande do Sul, (buses and trucks) and the new entrants, printed in red, wide spread in other regions such as Minas Gerais, Paraná, Bahia e Goiás. A comparison between 1990 and 2005 (Table 1) shows that the number of industrial plants now is more than twice the existents in early 1990's. In 2007 the market share of São Paulo State dropped to 40,7% due to a continuous delocalization trend of Brazilian automotive industry all over the country.

ANFAVEA Brazilian Automotive Industry Yearbook 2006 shows in Table 1 and Figure 2 this ongoing decentralization process of the automotive industry in Brazil.



Source: Projeto Cars/PADCT Brazil

**Figure 1.** Automotive industry plants in Brazil.

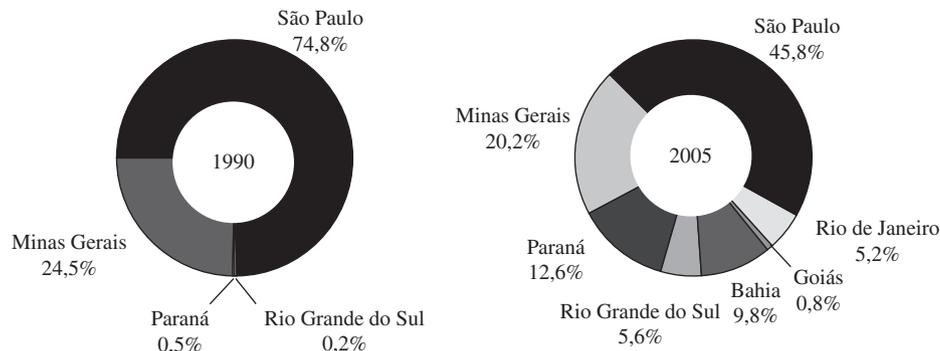
**Table 1.** Automotive companies in Brazil: regional distribution in 1990 and 2005.

Brazilian states	1990	2005
Rio Grande do Sul	Agrale, Marcopolo, Randon, SLC, AGCO	General Motors, Internacional
Paraná	Volvo, New Holland	VW/Audi, Chrysler, Nissan/Renault
Minas Gerais	FIAT	Daimler Chrysler, Iveco
São Paulo	Engesa, Ford, GM, Gurgel, Mercedes-Benz, Scania, Toyota, Volkswagen	Daimler Chrysler, Ford, GM, Honda, Land Rover, Scania, Toyota, VW.
Rio de Janeiro	-	PSA Peugeot-Citroën, VW Caminhões
Goiás	-	Mitsubishi
Bahia	-	Ford

Source: ANFAVEA (www.anfavea.com.br).

This growing decentralisation, and increasing number of new plants and new models, is changing the profile of the Brazilian automotive production in the present, with important impacts on post industrial recycling of parts and components requirements, and should represent a threat-opportunity situation in the next future. A threat in the sense that the new models are multimaterials and light-materials made which means more plastics and light metals alloys that were not developed in the country. An opportunity because

these new materials were conceived to be recyclable and most of them are produced domestically, by newcomers suppliers such as Plastic Omnium (PO) and Peguform that, among others, are global full-service-suppliers of plastics parts and components for automotive industry, designing and manufacturing and single plastic components, systems and complete modules as well. They came to add new blends to the traditional thermoplastics production Brazilian sector that was already the most important of Latin America.



Source: ANFAVEA (www.anfavea.com.br)

**Figure 2.** The Evolution of the regional distribution of automotive companies in Brasil.

From 1998 to 2003 Brazil doubled Polypropylene installed capacity and increased in 60% the internal sales, exporting only 15% of its internal production.

Nevertheless PO in France made Renault Megane and Clio bumpers from 35% of recycled polypropylene but in Brazil this proportion could not be as higher as 7%, which corresponds to the volume of industrial scrap recovered at the PO plant. This situation is due to the low quality of the recycled material, which cannot reach the stability standards requirements of new bumpers.

## 2. The environmental regulatory framework

Worldwide regulatory framework is pushing new design methods and practices for environmental purposes. The ELV Directive 2000/53/EC of the European Parliament and of the Council of European Union on End-of-life Vehicles adopted by European Union members in October 2000 is the state of art of a negotiation process, between interested parties, and public authorities that has lasted for a decade already. Since the Act of Political Union signed in Maastrich in 1992 institutions and regulatory methods are changing in environmental rule making within European Union. The firms are getting more and more involved in the regulatory process and the European automakers are not only establishing their own environmental policies but also acting as responsible for the implementation of a programme that depends both on suppliers and partners.

Regarding the recycling regulations for example, the French automakers were pioneers in Europe in promoting voluntary agreements between all firms involved and the government. A so-called “l’Accord Cadre” was signed in 1993. This agreement set up goals such as: at 2002 all vehicles produced should be 95% recyclable. On these proposes the French Companies: Peugeot, Citroën and Renault have been working together on assembling and “disassembling” technical specifications and materials

identifications reaching separation for recycling. It means that recycling criteria has to be integrated into all other functional requirements of the vehicle project. They also have to share this task, and the risks, with their suppliers, comprising the R&D expenses.

The central issue is that this regulatory framework has a great power of diffusion concerning global products such as vehicles. Furthermore increasing recyclability rate is also connected to the new system of Environmental Management Systems – EMS – largely regulated by ISO 14000 and other national standards systems of environmental quality. This is quite visible in the automobile industry worldwide especially in the plants, no matter where they are located. In this sense we have observed that the new plants in Brazil are a good example of this trend.

In this sense the Industrial Complex Ford Northeast, located at Camaçari in Bahia, which is designing vehicles since 2003, at its Latin America R&D Center, under the most restricted substances management standards (RSMS). They are part of the overall process of materials reporting and certification Ford program that includes the following enhancements and recommendations, based on the internal rules for product development last version 14 February 2006, presented by the engineers of the Latin American R&D Center of Ford during a technical visit made by the authors in 09/12/2006 to Ford Industrial Facilities in Camaçari:

- Leveraging Ford best practices, all parts that should be reported in the International Materials Data System (IMDS) will continue to be posted on the Global Materials Integration Reporting system (GMIR);
- Internal Ford practices are being strengthened to facilitate the up-front design of components free of restricted substances. At the same time, part manufactures must confirm design execution by complying with IMDS reporting requirements. New for 2006

is the expectation that suppliers provide initial part submission early in the product development cycle and supplemental detail later, concurrent with final part approval. This practice will improve data submission efficiency as parts advance through design levels. That means they follow a gate system pattern of evaluation that counts on a number of approvals throughout the product development phases;

- Reviews with select suppliers late in 2005 identified best practices for RSMS management. Building on those reviews, Ford recommends that suppliers manage IMDS reporting centrally and include RSMS compliance/IMDS reporting as regular part of senior management quality/QOS reviews. And finally; and
- Incorporation of the Global Automotive Declarable Substance List (GADSL) into RSMS.

This is surely a good opportunity for Brazilian engineers and designers to get into eco-design activities, which up to now concerns only the headquarters bureau employees. That is also a means of getting from all partners their contribution to the sustainability of automotive industry and of the vehicle itself. And besides, it contributes to organise a competitive automotive materials recycling sector in Brazil in terms of technical efficiency, economic viability, and environmental friendliness.

## 2.1. European directive on end of life vehicles

Based on French voluntary agreements (*l'accord cadre*, 1993) and on similar German regulation on end of life products (drawback law for packing) the European Directive 2000/53/EC aims at making vehicle dismantling and recycling more environmentally friendly, sets clear quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability.

The directive states in article 7.1 that for reuse and recovery purposes that preference to recycling must be given to the recovery of components, which cannot be reused when environmental viable recycling process is available, without prejudice to requirements regarding the safety of vehicles and environmental other requirements such as air emissions and noise control. This means that in terms of the sustainability for car industry recyclability does not assure sustainability. Sustainability claims for protection of human health and ecology, clean technologies (at both levels: production and recycling), enforced environmental legislation, well-organised collection systems and large market assuring secondary materials supply and demand for recycled materials. For these purposes automotive industry is supposed to be responsible for their products (vehicles or auto parts) from cradle to grave. That means that they have to close automotive materials life cycle loop reducing the existent ones and even avoiding extra environmental impacts.

Concerning recyclability rates, the Directive requires that “*Members States shall take the necessary measures to ensure that the following targets are attained by economic operators:*

- a) no latter than 1<sup>st</sup> January 2006, for all end-of life vehicles the reuse and recovery shall be increased to a minimum of 85% by an average weight per vehicle and year. Within the same time, limit the reuse and recycling shall be increases to a minimum of 80% by an average weight per vehicle and year; and
- b) no latter than 1<sup>st</sup> January 2015, for all end-of-life, vehicles, the reuse and recovery shall be increased to a minimum of 95% by an average weight per vehicle and year. Within the same time limit, the reuse and recycling shall be increased to a minimum of 85% by an average weight per vehicle and year;” (EUROPEAN PARLIAMENT and COUNCIL of the EUROPEAN UNION, 2000)

This Directive is supported by eleven other secondary legislations related on ELVs including Environmental Commission Decision, European Council Decision and a Commission Proposal for a Directive of the European Parliament and the Council on the type-approval of motor vehicles with regard to their re-usability, recyclability and recoverability amending Council Directive 70/156/EEC. And other five of them are on Annex II amending. Besides there are also secondary legislation at national level and The Commission services have developed a “Guide” on the legislative acquits, which aims at facilitating the implementation of the Directive and the secondary legislation at both levels.

Concerning eco-design proposes the Directive says that the requirements for dismantling, reuse and recycling of end-of-life vehicles and their components should be integrated in the design and production of new vehicles. And, furthermore, it states that producers should ensure that vehicles are designed and manufactured in such a way as to allow the quantified targets for reuse, recycling and recovery to be achieved.

The Directive also states that economic aspects of recycling have to be taken into account in order to promote a market for recycled materials (...) *The development of markets for recycled materials should be encouraged.* And for this purpose Member States are required to enforce the provisions of the Directive mainly regarding the access of small and medium sized enterprises to collection, dismantling, treatment and recycling market. Additionally, concerning a green market for recycled products the European Commission additionally to the directives on ELV and DEEE published in 2001 its so-called green book on Product Integrated Policy (PIP) intending to promote this market by means of eco-designed products. Professors at

the Center for Scientific Management of *l' Ecole de Mines de Paris*, say:

*l'adoption de pratiques d'eco-conception par les entreprises apparaît en particulier comme l'une des conditions de réussite de cette politique. Le livre vert propose sur ce point un nouveau référentiel pour le management de l'eco-conception: le POEMS (Environmental Oriented Environmental Management System) (ABRASSART; AGGERI, 2002).*

Nevertheless, carmakers are supposed to provide authorized treatment facilities with all requisite dismantling information, in particular for hazardous materials. The Annex I of the directive settles the minimum technical requirements for end of life vehicles treatment in accordance with the best environmental practices available. And the Annex II seeks to remove gradually the hazardous substances from automobile, such as heavy metals (Lead, Mercury, Cadmium and Chromium6), affecting particularly paint pigments and coatings against corrosion. This annex is supposed to be revised (and it really was for three times already) considering the state of art of materials and the availability of substitutes as well.

## 2.2. The Brazilian regulation on ELV and components

Brazilian environmental legislation started by controlling products and components containing hazardous substances such as: batteries, tyres, catalytic converters and other elements containing lead, mercury, copper, zinc, and chrome with regard to their recyclability and final disposal. Encompassing this legislation a new industrial sector is being organized on technical and economic basis: the automotive materials recycling. For this purpose there is also an ongoing discussion project of Federal Law on end of life vehicles (ELV) recycling since 1997.

Since the new automotive companies in the 2000's came mainly from Europe, a following the leader strategy is enforced. This strategy has multiplied the efforts and accelerated the contributions from eco-design to automotive materials recycling activities at both academic and industrial levels. At academic level, university laboratories and research centers are conducting a number of studies and technological developments to improve recycling processes. At industrial level, as lot of effort is being put on the organization of these activities in economic basis as an industrial sector. Besides the European Directive 2000/053/EC is speeding Brazilian environmental legislation on ELV and car components.

Batteries and tires have already Conama (National Council for Environment Standards attached to the Brazilian Ministry of Environment, (MMA, [199-])) resolutions on recycling and final disposal of recycling residues. There are also ongoing proposals for Federal laws on the recycling of these two components since the middle 1900's (1994 batteries, and 1995 tires). Industrial scrap from plastics

and metallic parts has been also object of discussion at the Federal Congress since 1997.

In 2005, after more than an eight-year discussion, two commissions in charge of the process of analysis approved a project of law on ELV recycling. This project first entered into the parliament debate in April 2<sup>nd</sup> 2000 and its second phase of negotiation and discussions can last for at least two more years.

Nevertheless, even if we have a state of art of environmental legislation on ELV in Brazil we have to face organizational and technological problems to cope with the requirements of a safe and sound vehicle recycling sector. Vehicle batteries, for instance, are recycled all over the world at different rates such as 95% in United States, 90% in European Union, and in Brazil this rate is estimated on an interval from 65 to 80%, varying according to the region. Even though in less developed countries the average rate is 50%, we are not in a good situation comparing to the regulatory framework we developed. Nowadays the recycling of batteries in Brazil is passing through a risk situation due to out-dated recycling technology based on pyrometallurgy processes. And, since the 1995, Environmental Federal Authorities shut down a number of informal lead smelters and even some big car companies plants. Long distance transportation of the used LAB (lead acid batteries) is another risky situation that remains. The environmental legislation is not enforced by an effective system at local level consequently there are still a large number of irregular final disposals.

Brazilian legislation on toxic substances is only about mercury (bulbs), lead (batteries, painting and coatings) and asbestos for some applications. Nevertheless asbestos for instance was banned from automotive components even in Brazil, due to the international restrictions. In this regard the new plants of Ford, Volkswagen, Peugeot-Citroen, and Renault-Nissan have already free lead painting and coatings processes. They have also the state of sound water treatment for both industrial effluents and used water from the industrial facilities.

## 3. Eco-design concept and practices

As we are dealing with an ongoing universe of concepts and practices it could be useful to highlight some definitions closely linked to the eco-design practices such as: eco-design itself, eco-tools, eco-materials, and automotive materials. Additionally we are going to give some examples of best environmental practices in Brazil linked to vehicle eco-design practices in Europe that are positively affecting vehicles recyclability in Brazil.

### 3.1. Eco-design concepts and definitions

- Eco-design

Broadly speaking, eco-design is the design approach that gets product design environmental oriented. In this

sense the project boundaries have been enlarged to include from materials selection to the end of life products and components recycling. More specifically eco-design is about adopting eco-tools to integrate environmental criteria on project and product development. It means to balance environmental requirements with the basic project requirements: cost, quality, safety, and delay. Products are firstly conceived to be efficiently mass-produced, and secondly to be dismantled and recycled when they become completely useless. In this sense eco-design methods and tools from conceptual design to detailed design- DFE, DFR, DFD, LCA, Eco Indicators, Eco-QFD- can be taken as a way out to overcome the dilemmas concerning car project decisions facing environmental demands.

- Eco-tools

Eco-tools are a set of instruments to translate environmental legislation and standards into project language. They include accurate tools such as internal guidelines, rules and standards, periodically reviewed, and dedicated software to get environmental criteria integrated in project data bases throughout the designing phases.

- Eco-materials

According to Halada one of the first contributors to the concept, it has been proposed in the early 90's in Japan throughout discussions about the future state of materials in the industrial production and their relation with the environment. The idea was to highlight the positive side of this relationship highlighting the benefits of the materials science and engineering to the ecology. In this sense, the concept is connected to Eco-design and life cycle designing since these developments were fostered by a holistic view of the ecosphere as result of interaction of as different systems as geo-system, bio-system and human-production-consumption-system. Halada classifies ecomaterials into four categories from a technological viewpoint: harmful-substance free type; low environmental profile type (including materials from recycled and from natural resources- renewable-); recyclable materials and; materials for efficient energy flow.

- Recyclable materials

As an important category of ecomaterials, recyclable materials have to be understood as part of a universe of continuous research, developments and improvements, which operates wider transformations than the designers and engineers had planned. In that way these materials had been transformed into economic and social concerns due to their contribution to more sustainable development models facing the ecological constraints of the extensive use of natural resources. They can be defined as materials that have the ability to be recycled, ie. technically feasible to be recycled. They include the distinct sub-category of recycled materials.

These materials have been largely developed for different industrial uses getting a significant effect on the design of industrial products in general, especially in such a complex product as a vehicle made of more than 20 thousands of parts and hundreds of different materials.

- Recycled materials

As part of the recyclable materials, the recycled materials are those that have economic viability to be reprocessed. Technically it can be defined as a material that has been reprocessed from recovered material by means of a manufacturing process and became a secondary raw material to be reintroduced into a final product or into a component production.

According to ISO 14021 there are two types of recycled materials:

- Post-consumer: material is material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product that can no longer be used for its intended purpose. This includes returns of material from the distribution chain.
- Pre-consumer: material is material diverted from the waste stream during a manufacturing process. It excludes the re-utilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.
- Recyclability: recyclability is the ability of a material to be recycled. For automobile industry, according to ACEA - the European Automobile Manufacturers Association - the factors that determine the recyclability of single materials and components include the purity of the recovered products, the market for the recovered products, the monetary value of the material, the cost of collection and transport, the cost of sorting, the cost of transformation into reusable material and the cost of disposing of any residual material.

This is exactly what DFR (Design for Recycling) practices are looking for: to provide an added value recycling condition to new products at the end of their life. DFR is a new concept of the design activity that incorporates materials recyclability from the very beginning of the product creation, i.e. as early as the concept design and materials selection pre-project phases. So complex products like automobiles have to be designed to be assembled and disassembled, and to be made as much as possible of recyclable and recycled materials.

### 3.2. Eco-design and recycling practices

So eco-designing a product as complex as a car aiming at minimizing its environmental impact over its whole life cycle is not an easy task. In Europe, for instance, car companies

are putting a great expertise, time and money into combining environmental and quality evaluation with designing tools in order to settle permanent basis for eco-design practices. And they are also enforcing partnerships with not only their traditional supplier but also with materials producers and recyclers. In this sense they are co-designing new models sharing integrated software and data basis.

As required by European Directive recyclability has to be incorporated into project practices by means of national and international environmental standards (ISO 14000 series) and design tools (internal guidelines for eco-design).

Our case study, conducted at Technocentre Renault, verified that the diffusion of eco-design practices is participating in all vehicle development phases and altering the profile of project team. Multidisciplinary design teams were formed in order to accelerate as much as possible environmental criteria diffusion and to get contributions from different areas of expertise to validate the environmental friendliness materials choice. As a result they get both innovative and recyclables models that not only fits the present environmental regulation, but also anticipate future requirements.

On the other hand, based on our studies and our knowledge of local designing and recycling practices of the big world class vehicles manufactures at their new plants and suppliers, in Brazil we can state that the environmental engagement that European Directive on ELV promoted is having a good impact on Brazilian automotive and recycling sectors.

To reach directives recyclability rates targets of 95% (including 85% of direct recycling) by 2015, the great challenge is on the plastic materials, since for metallic materials already 5% recycled, and free from toxic substances there is no big problem. The most important efforts are being put into reducing the remaining 25%. A great number of actions have been taken by European national government in translating these exigencies into national legislation in setting networks at research and industrial level as well. In cooperation with the automotive companies and materials producers they are enforcing plastics recyclability and promoting recycling initiatives.

For plastic parts the problem is not only in the material itself but also in the design of the part, in the joining required to assembly the system, in the painting and in the final assembly process. Furthermore, this recyclability is affected by the most used ELV recycling system in Europe, at the present, which can be classified as semi-dismantling and shredder that gets a great volume of plastics into ASR (Automotive Shredder Residues). According to the soundest scenario for vehicle recycling the main trend is to have 4 main phases:

Phase 1: pre-treatment including: decontamination and dismantling related to toxic substances regulation

Phase 2: dismantling including bumpers, windscreen, side windows, tires and other parts easy to dismantle for reuse or recycling

Phase 3: metal separation, including shredder, and sorting ferrous and non-ferrous metals up to recycling

Phase 4: non-metallic residue treatment including recycling and energy recovery as well.

So, according to Renault materials specialists the objective of 95% will be obtained by improving the second phase i.e. dismantling of parts, made of recyclable materials, which includes a increasing volume of plastics, which reached to 15% of car weight by 2005. In this sense a new trend is reducing plastic diversity as much as possible and selecting new plastics with their chemical compatibility in mind. Compatibility is also important with regard to joining and coatings to avoid extra contamination that can reduce the component ability to be dismantled and recycled, i.e. the rate of recyclability.

#### 4. Open questions, final remarks and recommendations

Even though the automotive chain in Brazil, car vehicles manufactures and suppliers, comprises foreign multinational companies, the materials industry (CVRD, CSN, Gerdau etc) are originally controlled by big national companies, and the recycling sector is locally based on small and medium enterprises. So the organization of recycling activities into competitive and sound environmental basis depends, on great extent, on the existence of internal capability of R&D, for clean technologies development for materials and for recycling as well, of product design, especially regarding DFE, DFR, DFA and Dissassembly methods, to encompass the international trends on these domains. That means that governamental policies for industrial technology development as integrated as the Product Integrated Policy (PIP) of European Commission could make the difference.

In a global view, the most important trends concerning vehicles recyclability that Brazil has to face in the next decade and that can be associated to the influence of European Directive and European automotive companies best practices are:

- The increasing volume of recyclable plastics in vehicles;
- The growing materials substitution towards eco-material such as renewable and recyclable material, materials for new sources of energy (fuel cells, electric cars...);
- The multimaterials profile of the new vehicles; and
- Technological innovation on recycling process to encompass materials complexity evolution.

## 4.1. Some open questions

Some important questions can be pointed out about Brazilian industrial and technological and design and engineering capabilities to answer to the recycling challenges into the next future:

- Is the existing materials recycling technologies in Brazil sufficient to assure the quality of recycled materials to automotive industry?
- Where and what would probably be the technological gap to recycle new vehicles from now to 2020?
- In the case of a boom of recycling activity by small and medium companies and artisan initiatives would it be accompanied by environmentally sound management?
- Is there a role for technology transfer to product designers and engineers at the local automotive parts and materials producers as well as materials recyclers to improve the efficiency of recycling activity?

## 4.2. Final remarks and recommendations

It must be recognised that there are different local conditions relating to factors as diverse as existing technology and expertise, the size of the market for recycling, energy costs and levels of information exchange on vehicles design for recycling between Brazil and European Community countries. But, on the other hand, the pressures from car industry globalisation were also hampering an exchange of recycling technology experience between regions and countries.

For recycling there is a great need to focus on identifying a range of ecomaterials options and clean processes for the next future that may be appropriate for different local scenarios of car recycling. This process was especially important in a world of continuous technological change in products as well as in materials and recycling technologies.

Emerging and developing economies such as Brazil should develop or get access to appropriate technologies and materials their limited but growing market, cost efficient, affordable and easy to use. It must be also said that recycling technology has to be environmentally sustainable and supported by up to date information on automotive materials trends and eco-design practices. For this purpose there should be:

- Communication at local level along the value chain so that recyclers are informed of changes in their feed composition while designers are aware of the need to design for recycling allowing adaptations in recycling technology as well;
- Co-operative multilateral efforts, between developed and developing countries, so as to build recycling expertises, best practices and to exchange information

on technology either through technical universities, or possibly the regional technology centres; and

- Technological transfer to provide a critical assessment of existing sound and efficient recycling technologies to developing countries, minimizing environmental benefits of eco-design practices worldwide.

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## 6. References

- ABRASSART, C.; AGGERI, F. **La Naissance de l'Eco-conception**: du cycle de vie du produit au management environnemental. Paris: Environnement Annales des Mines, 2002. p. 41-63. Série trimestrielle des Annales des Mines, éditions ESKA. Available from: <<http://www.anales.org>>.
- ASSOCIAÇÃO NACIONAL DE FABRICANTES DE VEÍCULOS AUTOMOTORES – ANFAVEA. Available from: <[www.anfavea.com.br](http://www.anfavea.com.br)>.
- Di NAPOLLI, A. **Customer-supplier relationships in radical outsourcing**: the case of Volkswagen modular consortium in Brazil. 2002. Thesis (Master in International Business) - Business School of Goteborg University, Sweden.
- EUROPEAN AUTOMOBILE MANUFACTURERS ASSOCIATION – ACEA. Available from: <[www.acea.be](http://www.acea.be)>.
- EUROPEAN PARLIAMENT; COUNCIL OF THE EUROPEAN UNION. **Directive 2000/53/EC of the European Parliament and of the Council, on end-of-life vehicles**. Available from: <[http://europa.eu.int/comm/environment/waste/elv\\_index.htm](http://europa.eu.int/comm/environment/waste/elv_index.htm)>.
- JERRAM, L. C. 2008 Bus Survey. Available from: <<http://www.fuelcelltoday.com/media/pdf/surveys/2008-Bus-Survey.pdf>>.
- MINISTÉRIO DO MEIO AMBIENTE - MMA. Conselho Nacional do Meio Ambiente. **National council for environment standards attached to the Brazilian Ministry of Environment**. Brasília, [199-]. Available from: <<http://www.ambiente.gov.br/sitio/>>.
- SHIMOKAWA, K.; JUÜRGENS, U.; FUJIMOTO, T. **Transforming automobile assembly**: experience in automation and work organization. Berlin: Springer Verlag, 1997. p. 1-16.

